Strategy Research Project

NUCLEAR ENERGY: IT IS TIME TO REVITALIZE THE PEACEFUL ATOM

BY

COMMANDER ERIC L. MASON
United States Navy

USAWC CLASS OF 2011

U.S. Army War College, Carlisle Barracks, PA 17013-5050

The U.S. Army War College is accredited by the Commission on Higher Education of the Middle State Association of Colleges and Schools, 3624 Market Street, Philadelphia, PA 19104, (215) 662-5606. The Commission on Higher Education is an institutional accrediting agency recognized by the U.S. Secretary of Education and the Council for Higher Education Accreditation.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
15-03-2011	Strategy Research Project	

4. TITLE AND SUBTITLE

Nuclear Energy: It is Time to Revitalize the Peaceful Atom

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Commander Eric L. Mason

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Captain James Heffernan
Department of Command, Leadership, and Management

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army War College
122 Forbes Avenue
Carlisle, PA 17013

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution A: Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Fossil fuels currently provide more than 85% of all the energy consumed in the U.S., nearly two-thirds of our electricity, and virtually all of our transportation fuels. The U.S.' reliance on fossil fuels will undoubtedly increase as we seek to expand our economy, but dwindling fossil-fuel supplies and climate change concerns are forcing the U.S. to consider alternate energy sources. Renewable energy sources, including wind, solar, geothermal, biomass, and hydro power must play a more important, and increasing role in our nation's energy mix. Despite previous reluctance to use nuclear energy in the past, nuclear power can and should play a greater role in meeting America's future energy demand. It can generate sufficient electricity safely while improving our energy security and protecting our environment.

15. SUBJECT TERMS

NRC, MW, NP2010, ESP, GHG, COL, ROI

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
UNCLASSIFED	UNCLASSIFED	UNCLASSIFED	UNLIMITED	30	

USAWC STRATEGY RESEARCH PROJECT

NUCLEAR ENERGY: IT IS TIME TO REVITALIZE THE PEACEFUL ATOM

by

Commander Eric L. Mason
United States Navy

Captain James Heffernan
Project Adviser

This SRP is submitted in partial fulfillment of the requirements of the Master of Strategic Studies Degree. The U.S. Army War College is accredited by the Commission on Higher Education of the Middle States Association of Colleges and Schools, 3624 Market Street, Philadelphia, PA 19104, (215) 662-5606. The Commission on Higher Education is an institutional accrediting agency recognized by the U.S. Secretary of Education and the Council for Higher Education Accreditation.

U.S. Army War College
CARLISLE BARRACKS, PENNSYLVANIA 17013

ABSTRACT

AUTHOR: Commander Eric L. Mason

TITLE: Nuclear Energy: It is Time to Revitalize the Peaceful Atom

FORMAT: Strategy Research Project

DATE: 16 March 2011 WORD COUNT: 5,748 PAGES: 30

KEY TERMS: NRC, MW, NP2010, ESP, GHG, COL, ROI

CLASSIFICATION: Unclassified

Fossil fuels currently provide more than 85% of all the energy consumed in the U.S., nearly two-thirds of our electricity, and virtually all of our transportation fuels. The U.S.' reliance on fossil fuels will undoubtedly increase as we seek to expand our economy, but dwindling fossil-fuel supplies and climate change concerns are forcing the U.S. to consider alternate energy sources. Renewable energy sources, including wind, solar, geothermal, biomass, and hydro power must play a more important, and increasing role in our nation's energy mix. Despite previous reluctance to use nuclear energy in the past, nuclear power can and should play a greater role in meeting America's future energy demand. It can generate sufficient electricity safely while improving our energy security and protecting our environment.

NUCLEAR ENERGY: IT IS TIME TO REVITALIZE THE PEACEFUL ATOM

> On an issue that affects our economy, our security, and the future of our planet, we can't continue to be mired in the same old stale debates between left and right, between environmentalists and entrepreneurs. Our competitors are racing to create jobs and command growing energy industries. And nuclear energy is no exception.
>
> —President Obama
> February 16, 2010

Fossil fuels currently provide more than 85% of all the energy consumed in the U.S., nearly two-thirds of our electricity, and virtually all of our transportation fuels. The U.S.' reliance on fossil fuels will undoubtedly increase as we seek to expand our economy, but dwindling fossil-fuel supplies and climate change concerns are forcing the U.S. to consider alternate energy sources. Renewable energy sources, including wind, solar, geothermal, biomass, and hydro power must play a more important, and increasing role in our nation's energy mix. Despite previous reluctance to use nuclear energy in the past, nuclear power can and should play a greater role in meeting America's future energy demand. It can generate sufficient electricity safely while improving our energy security and protecting our environment.

On 26 May 1958, President Eisenhower opened the first U.S commercial nuclear power plant in Shippingport, Pennsylvania. As nuclear power continued to grow throughout the 1960s, the Atomic Energy Commission anticipated that more than 1,000 reactors would be operating in the U.S. by 2000.[1] There are 104 nuclear power plants currently operating in the U.S., and while there are plans for a number of new reactors, ground has not been broken on any new commercial nuclear plant sites since the 1970s. While 30 countries around the world have accepted nuclear power as a

significant contributor towards meeting their ever-increasing demand for energy, the U.S. has fallen behind.[2] The time has come for a nuclear renaissance in the United States. U.S. nuclear energy policy must account for the changed world we now live in. Relying on old policy reflecting unsubstantiated and exaggerated risks and fears must end.

Fossil-Fuels

The nation's reliance on fossil fuels to power an expanding economy will increase over at least the next two decades even with aggressive development and deployment of new renewable and nuclear technologies.[3] The U.S. Energy Information Administration released the *Annual Energy Outlook 2011 with Projections to 2035*, evaluating a wide range of trends and issues that could have major implications for U.S. energy markets. The report predicts that total U.S. consumption of liquid fuels, including both fossil liquids and biofuels, will grow from 36.6 quadrillion Btu (18.8 million barrels per day) in 2009 to 41.8 quadrillion Btu (22.0 million barrels per day) in 2035. The transportation sector dominates demand for liquid fuels from 72 percent of total liquids consumption in 2009 to 74 percent in 2035. Additionally, the report states natural gas consumption will rise from 22.7 trillion cubic feet in 2009 to 26.5 trillion cubic feet in 2035 and total coal consumption, which was 22.7 quadrillion Btu in 2007, increases from 19.7 quadrillion Btu in 2009 to 25.2 quadrillion Btu in 2035. Coal consumption, mostly for electric power generation, grows gradually throughout the projection period, as existing plants are used more intensively.

Recently, the Obama administration's decision to halt offshore drilling in the Atlantic, Pacific and the eastern Gulf of Mexico for the next seven years will significantly impact domestic oil production. Coupled with the public’s reluctance to permit new

electric generation, of any kind, near their homes, the nation's electricity supply surplus has slowly eroded.[4] Additionally, the rapid growth of China and India matched with the developed world's dependence on oil, mean that a lot more oil will have to come from somewhere.[5] Fereidun Fesharaki, senior associate at the Center for Strategic International Studies, forecasted China's oil use to rise by around 400,000 barrels a day for each of the next eight to 10 years, and India's annual growth will be 100,000 to 150,000 barrels a day.[6]

> Whether fossil fuels run out in 20 years or 200 years is not really important. Both industrialized and developed nations require greater amounts of energy on an annual basis. This will increase competition for energy sources, raise prices, and give energy suppliers greater power in the market.[7]

Rising Energy Prices

Across the U.S., as across much of the world, rising energy prices are less a momentary blip than a lasting change with consequences.[8] The price of crude oil has increased from $20 per barrel in the 1980s to as much as $100 per barrel in the past few years. Natural gas prices have seen an increase during the same time span, from $3 per million Btu to an average of nearly $9 per million Btu. Recent higher crude oil and natural gas prices have given coal producers pricing power to raise prices.[9] However, coal plants may become increasingly difficult to build because of public awareness of their environmental impact.[10] Since 1998, regulatory restrictions implemented by the Clean Air Act Amendments of 1990 have reduced sulfur dioxide and nitrogen oxide emissions by 55.7 percent and 62.9 percent, respectively. The environmental regulatory restrictions imposed have increased fossil fuel-generated electricity costs because cleaner energy means additional capital assets to meet regulations and these charges go back to the consumer. These higher fuel costs make

the case for nuclear power even stronger now than in the past.[11] Table 1 shows a comparison in electricity production costs amongst the various sources of energy. It demonstrates that nuclear power electricity production from 1995-2009 was cheaper than all other major sources of electricity production. Table 1 also shows the increasing cost of coal and gas production. These cost increases in production are transferred to the consumer.

U.S. Electricity Production Costs and Components
1995 - 2009, In 2009 cents per kilowatt-hour

NEI
NUCLEAR ENERGY INSTITUTE

	Total Production Costs				Operations & Maintenance Costs				Fuel Costs			
Year	Coal	Gas	Nuclear	Petroleum	Coal	Gas	Nuclear	Petroleum	Coal	Gas	Nuclear	Petroleum
1995	2.56	3.73	2.69	5.83	0.61	0.71	1.89	1.64	1.96	3.02	0.80	4.20
1996	2.41	4.56	2.52	5.93	0.54	0.70	1.80	1.36	1.88	3.86	0.72	4.57
1997	2.33	4.62	2.64	5.33	0.52	0.67	1.93	1.16	1.81	3.95	0.71	4.17
1998	2.28	4.04	2.45	3.75	0.55	0.61	1.75	0.72	1.73	3.44	0.70	3.03
1999	2.20	4.37	2.21	4.50	0.52	0.51	1.57	1.02	1.67	3.86	0.64	3.47
2000	2.15	7.24	2.16	6.48	0.51	0.57	1.56	0.80	1.63	6.67	0.60	5.69
2001	2.20	7.30	2.05	5.99	0.54	0.64	1.48	0.82	1.66	6.66	0.56	5.17
2002	2.18	4.63	2.01	5.71	0.55	0.62	1.49	0.93	1.63	4.01	0.53	4.78
2003	2.15	6.37	1.98	6.86	0.55	0.66	1.44	1.09	1.60	5.72	0.53	5.77
2004	2.23	6.40	1.93	6.52	0.57	0.55	1.41	0.98	1.66	5.85	0.53	5.54
2005	2.42	7.99	1.87	8.94	0.57	0.53	1.38	0.97	1.85	7.47	0.49	7.97
2006	2.52	6.91	1.90	10.31	0.59	0.54	1.42	1.38	1.93	6.37	0.49	8.93
2007	2.57	6.68	1.89	10.78	0.60	0.52	1.39	1.45	1.96	6.16	0.50	9.33
2008	2.80	7.80	1.96	17.63	0.60	0.53	1.46	1.94	2.20	7.27	0.51	15.69
2009	2.97	5.00	2.03	12.37	0.67	0.56	1.46	2.55	2.30	4.44	0.57	9.82

Production Costs = Operations and Maintenance Costs + Fuel Costs. Production costs do not include indirect costs and are based on FERC Form 1 filings submitted by regulated utilities. Production costs are modeled for utilities that are not regulated.
Source: Ventyx Velocity Suite
Updated: 5/10

Table 1

U.S.' Energy Policy

> The U.S. has a window of opportunity to lead in the development of clean energy technology. If successful, the U.S. will lead in this new Industrial Revolution in clean energy that will be a major contributor to our economic prosperity. If we do not develop the policies that encourage the private sector to seize the opportunity, the U.S. will fall behind and increasingly become an importer of these new energy technologies.[12]

Nuclear power plants generate approximately 20 percent of electricity produced in this country; however, all recent electric-generating capacity additions and projected

future additions are primarily fueled by natural gas. Despite the performance of current nuclear plants and decisions by power plant owners to seek license renewal, no new plant has been ordered in this country for more than 30 years. The Bush and Obama administrations have passed legislation and proposed initiatives to reduce risk and uncertainty associated with building (licensing, citing, and financing) nuclear power plants.

The U.S. Energy Policy Act in 2005 is one of the cornerstones to the renaissance of nuclear power in the U.S. since it provides several key financial incentives in the form of loan guarantees and tax credits.[13] Spurred by rising energy prices and growing dependence on foreign oil, the new energy law was shaped by competing concerns about energy security, environmental quality, and economic growth.[14] Title VI of the law provides financial incentives through loan guarantees, tax credits, and regulatory delay compensation for innovative technologies that avoid greenhouse gases, such as nuclear reactors, as well as clean coal and renewable energy.

The 2005 Energy Policy Act authorizes $18.5 billion in loan guarantees, but none have been issued. The Act gives the Secretary of Energy authority for loan guarantee approvals up to 80 percent of the cost of advanced energy projects, including fossil fuel, renewable, nuclear, and energy efficient technologies. President Obama has proposed tripling that amount to expand nuclear power as a way to control greenhouse gas (GHG) emissions and bolster domestic energy production.[15] His budget proposal for 2011 would add $36 billion in new federal loan guarantees for a total of $54.5 billion.

The Energy Policy Act's strongest nuclear incentive is a 1.8-cents/kilowatt-hour tax credit for electricity produced by nuclear reactors. The credit is available for up to

6,000 megawatts (MW) of new capacity — the equivalent of about five or six new reactors — for the first eight years of operation. These incentives serve to reduce financial risk to nuclear energy project investors.

The biggest obstacle to building a new nuclear power plant is the economic risk for the investor; an eleventh hour legal challenge or regulatory hurdle could quickly arise that would render the plant inoperable.[16] To counter the enormous expense of constructing a nuclear reactor and the possible delays associated with obtaining an operating license, the Act provides risk insurance for private financiers. The Seabrook reactor in New Hampshire could have benefited from this insurance. It was projected in 1976 to cost $850 million and to be completed in six years. Due to construction delays, cost overruns and troubles obtaining financing, the power plant actually cost $7 billion and was not complete until 1990.[17] The delay led to the bankruptcy of Seabrook's major utility owner, Public Service Company of New Hampshire.

Similar to nuclear power plant construction delays, the trend over several years of conventional power plant construction has taken longer due to project delays. Delays and cancellations have been attributed to regulatory uncertainty regarding climate change or strained project economics due to escalating costs in the industry. The regulatory uncertainty for greenhouse gas legislation is a key issue impacting technology selection and the reliability of economic forecasts and financial risk. Today, returns on investment (ROI) are more uncertain for conventional plants and those previously predictable ROIs can be severely compromised by the need to subsequently address carbon dioxide mitigation.

Under the Energy Act the first two nuclear reactors that receive combined construction and operating licenses and are under construction will receive insurance coverage for 100 percent of any potential cost of delay, up to $500 million per contract. The next four units will be covered for 50 percent of the costs of the covered delays, up to $250 million per contract, after an initial 180-day period. This makes the ROIs on nuclear plants much less risky while conventional plant ROIs with unsettled environmental legislation are assuming much more risk.

To further counter delays, the Nuclear Power 2010 program (NP2010), unveiled by the Department of Energy, is a joint government/industry cost-shared effort to identify sites for new nuclear power plants and to bring to market advanced nuclear plant technologies, to evaluate the business case for building new nuclear power plants, and to demonstrate untested regulatory processes.[18] The early site permit (ESP) process supported as a part of the NP2010 program enables completion of the site evaluation component of the nuclear power plant licensing before a utility makes a decision to build a plant. Successful completion of the ESP process will establish that a site is suitable for possible future construction and operation of a nuclear power plant, resolving significant safety and environmental issues early in the decision process. This process will avoid the siting problems that vastly escalated the costs of some plants in the 1980s and led to the abandonment of others.[19] The timeframes for NRC's North Anna, Virginia, Clinton, Illinois, and Grand Gulf, Mississippi ESP application reviews ranged from 41 to 50 months. NRC estimates that the more recent Vogtle ESP application will be completed in 37 months (25 months for ESP review and 12 months for the mandatory hearing process).[20]

Financial Construction Costs

Nuclear power plants are expensive to build but relatively inexpensive to operate, because their fuel costs are low compared with alternatives.[21] A new 1,000 MW nuclear plant costs $1.5 to 2.0 billion and takes approximately five years to build.[22] However, "bottlenecks in the supply chain, including ultra-heavy forgings, large manufactured components, engineering, craft labor, and skilled construction"[23] have caused plants under construction to be delayed.

Additionally, cost overruns for plants built in the US in the 1970's and 1980's have hurt nuclear reactor construction's economic viability. Table 2 shows historical data of US construction costs from 1966-1977.

Historical US construction costs

Construction started	Estimated overnight cost ($/kWe)	Actual overnight cost ($/kWe)	% over
1966-67	560	1170	209
1968-69	679	2000	294
1970-71	760	2650	348
1972-73	1117	3555	318
1974-75	1156	4410	381
1976-77	1493	4008	269

Data for 75 plants operating in 1986 in 2002 dollars
Source: EIA

Table 2

The reasons for costs overrun include:

- *Design Flaws*. There were significant design flaws which led to the reactor leak and operator confusion that caused the Three Mile Island accident. After these were exposed, the US Nuclear Regulatory Commission (NRC) undertook an extensive review of Nuclear Plant designs and in many cases ordered changes. These changes were both expensive and time consuming to fix. They led to extensive construction delays at a time of very high interest rates and so significantly increased the cost of the Capital required to build the plant.[24]
- *Two hurdle licensing*. Up until the mid-1990's developers of nuclear power plants had to obtain both a license to build a Nuclear Power then a subsequent license to operate the plant. This also delayed the start of plant operation which significantly increased the cost of the plant. The worst situation was that of the Shoreham Plant which was completed on Long Island in New York State at a cost of $5 billion but was never allowed to operate.[25]
- *Non-uniform designs*. The US Nuclear Power Industry never achieved economies of volume because every reactor design was different. Each developer put in their own tweaks and much of the equipment was custom built for each plant. This compounded the difficulties of obtaining NRC licensing approval since the NRC had to evaluate each individual design.[26]

Nuclear Waste

James Lovelock, an independent scientist and environmentalist stated

> An outstanding advantage of nuclear over fossil fuel energy is how it is to deal with the waste it produces. Fossil fuel burning produces twenty seven thousand million tons of carbon dioxide yearly. This is enough if solidified to make a mountain nearly two kilometers high and with a base ten kilometers in circumference. The same quantity of energy if it came from nuclear reactions would make fourteen thousand tons of high level waste. A quantity that occupies a sixteen meter sided cube.[27]

Each regular 1000 MW nuclear power plant generates 30 tons of radioactive waste annually.[28] Waste from a nuclear plant is primarily a solid waste, spent fuel, and some process chemicals, steam, and heated cooling water.[29] Nuclear waste differs from a fossil fuel plant's waste because its volume and mass are minute compared to the electricity produced.[30] A similar amount of electricity from coal would yield over 300,000 tons of ash, assuming 10% ash content in the coal.[31]

Nuclear power also produces no notable sulfur oxides, nitrogen oxides, or particulates. Compared with coal, nuclear power does produce spent fuels of roughly the same mass and volume as the fuel that the reactor takes in. While fossil fuels emit stack gasses to the ambient environment, solid wastes at nuclear power plants are contained throughout the generation process; no particulates or ash are emitted. Waste from the nuclear power plant is managed to the point of disposal, while a substantial part of the fossil fuel waste, especially stack gases and particulates are unmanaged after release from the plant.[32]

A major general public concern regarding nuclear power generation is nuclear waste disposal. In 2002, the U.S. Congress approved The Yucca Mountain Repository as a deep geological repository storage facility for spent nuclear fuel and other radioactive waste. It is located between the Mojave Desert and the Great Basin Deserts in Nevada, approximately 90 miles from Las Vegas. Capable of storing approximately 77,000 tons of nuclear waste, to date, Yucca Mountain has not received a single shipment.

In 2009 the Obama Administration stated that the site was no longer an option and proposed to eliminate all funding in the 2009 U.S. federal budget.[33] On 3 March

2010, the Secretary of Energy submitted a motion to withdraw the Department of Energy's pending license application for the permanent repository at Yucca Mountain. In the motion he stated:

> It is the Secretary of Energy's judgment that scientific and engineering knowledge on issues relevant to disposition of high-level waste and spent fuel has advanced dramatically over the twenty years since the Yucca Mountain project was initiated…Future proposals for the disposition of such materials should thus be based on comprehensive and careful evaluation of options supported by that knowledge, as well as other relevant factors, including the ability to secure broad public support, not an approach that "has proven effective" over several decades.[34]

In order to revitalize the peaceful atom, we must locate a disposal site that the public will find acceptable. Additionally, we should seek innovations to reduce the amount of waste produced. Almost 100 percent of the material in a spent nuclear fuel rod can be recycled as useful material and is being done so in France. However, in the U.S., for both policy and economic reasons, final disposition involves the ultimate burial of all spent fuels from nuclear power plants.[35] Spent fuel is intensely radioactive, and reprocessing is a complex chemical operation that separates plutonium from those elements in spent fuel that make it highly radioactive. At that point the plutonium can be used to make new reactor fuel or nuclear weapons. For this reason, there has been a long-standing concern that reprocessing facilities anywhere would be potential sources for terrorists seeking the materials required to make nuclear weapons, and that such facilities could ease the path for nations beginning nuclear weapons programs.[36] These concerns led the U.S. to abandon its reprocessing program in the 1970s.

Kyoto Protocol and GHG Emissions

The Kyoto Protocol mandates emission level targets for 37 industrialized countries and the European community for reducing GHG emissions .These amount to

an average of five percent below 1990 levels over the five-year period 2008-2012. The ratification treaty covers more than two-thirds of total GHG emission sources, in more than 160 countries. Entered into force on 16 January 2005, the Protocol requires countries to meet their emission target levels through national measures, but offers them an additional means of meeting their targets by way of three market-based mechanisms: 1) emissions trading, 2) clean development mechanism, and 3) joint implementation.[37]

Although the U.S. was a signatory to the Protocol, the U.S. Senate voted 94-2 to reject the Kyoto Protocol citing potential damage to the U.S. economy required by the compliance. The Senate also refused to ratify the agreement because it excluded certain developing countries, including India and China, from having to comply with new emissions standards. In 2008, a bill to impose a tax on carbon emissions was debated for a week but met strong resistance and never came to a vote.[38]

Despite the lack of ratification, U.S. cities, states, and regions have taken the initiative to reduce carbon dioxide emission levels. The industrial region stretching from New Jersey to Maine generates approximately the same volume of carbon dioxide as Germany.[39] A regional agreement was made amongst the Northeast states to reduce CO_2 from big power stations by 15 percent by 2020.[40] Limits to carbon emissions are evolving domestically without Kyoto efforts, and "limits would directly impact the potential for growth of coal-fired generation, which creates substantial emissions unlike other forms of fuel."[41] Nuclear power plants release no carbon emissions, supporting the Kyoto Protocol's objective, and allowing the U.S. to assist in the global effort to reduce greenhouse gases. In the future, global pressure to reduce U.S. greenhouse gases will

only increase and nuclear power plants enable the U.S. to reach that future of reduced emissions.

Renewable Energy

The Department of Energy is considering several alternative solutions for energy security supporting the extreme urgency of countering climate change. *The New Scientist*, a well known scientific journal published in the United Kingdom and the U.S., recently editorialized that:

> Although renewable electricity technologies are heavily criticized by the nuclear, coal, and oil industries and by many politicians…the combination of wind power, tidal-power, micro-hydro, and biomass are now almost as cheap as coal, and wave power and solar photovoltaics are rapidly becoming competitive.[42]

Renewable energy believed to be quick to build, flexible, secure, and climate friendly has accounted for 6 percent of the U.S. total contribution to electricity since 1970.[43] Although renewable energy sources play an important role in our nation's energy mix, they will continue to play a complimentary role as long as they are not constant and reliable energy sources.

Wind Power. Wind energy has enormous potential in the U.S. The U.S. has installed capacity just past 20,000 MW and "it is growing at 25 percent a year."[44] A recent study found a potential global wind power resource of 72 terawatts-forty times the amount of electricity used by all countries in 2000.[45] The average price of wind power has gone down; from 10 cents per kilowatt hour to about 5 cents per kilowatt hour in some areas prevailing winds are competitive with natural gas generation.[46]

Wind power has its disadvantages as well. Concern has grown over bird kills and the scenic impact. To produce 1,000 MW of installed capacity, the same amount of power one nuclear reactor could generate, a wind farm would require about 60,000

acres, or about ninety-four square miles, according to the American Wind Energy Association. A nuclear plant only requires 4 acres.

Additionally, the problem with wind energy is that it fluctuates. The wind never blows steadily anywhere in the world. While nuclear plants can maintain steady levels of power, wind can fluctuate from minute to minute. Most windmills produce electricity less than one-third of the time.[47] This requires another power source to ensure demands are met when the wind is not blowing.

Solar Power. Direct solar holds the greatest promise for helping cut carbon emissions and provide alternate means of energy.[48] It has been estimated that an inefficient photovoltaic array covering half a sunny area measuring 100 square miles could meet all the annual U.S. electricity needs.[49] Although night demand is problematic, solar energy has an advantage over wind because it peaks when it is most needed-hot summer afternoons.

Despite incentives, it is still relatively expensive to construct a solar system. In October 2010, the U.S. approved a permit for the largest solar energy project in the world -- four massive solar plants at the cost of one billion dollars each in southern California.[50] When completed the project is expected to generate up to 1,000 MW of energy, enough electricity to power up to 300,000 average American homes. Unfortunately, the estimated $4 billion, 7,000-acre project equates to a single, $2 billion nuclear plant.

Geothermal Power. Geothermal sites have tapped for energy for quite some time. In China, geothermal waters are used in agriculture and aquaculture to prevent damaging frosts and extend the growing season. In Romania, geothermal waters are

used to heat numerous homes and acres of greenhouses, and industrial hot water for factories. In the U.S., Hawaii gets 25 percent of its electricity from geothermal energy, Nevada 10 percent and California 5 percent. 8,000 MW are produced for twenty nations using geothermal energy.[51]

However, geothermal steam sites have their problems. Geothermal sites that vent to the surface for direct conversion to electricity via turbines are scarce. At most sites, steam can only be extracted by cutting through geographical layers. Also, the hot water or steam often contains high levels of poisonous hydrogen sulfide.

Base load electricity is required twenty four hours a day. Wind power is intermittent. The sun does not shine at night, and its intensity is weakened by overcast skies. Additionally, there are limited geothermal sites throughout the U.S. If the U.S. wants an energy source capable of a constant electricity supply, nuclear power is the path to pursue. Nuclear power can generate substantial base load electricity without carbon or other GHG emissions.

Three Mile Island: A Cause for No New Construction

The accident at the Three Mile Island Unit 2 (TMI-2) nuclear power plant near Middletown, PA, on March 28, 1979, was the most serious in U.S. commercial nuclear power plant operating history. The accident led to no deaths or injuries to plant workers or members of the nearby community. Estimates are that the average dose to about 2 million people in the area was only about 1 millirem. To put this into context, exposure from a chest x-ray is about 6 millirem. Compared to the natural radioactive background dose of about 100-125 millirem per year for the area, the collective dose to the community from the accident was very small.[52]

Two weeks prior to the accident at TMI, coincidently, *The China Syndrome* was released in the theatre creating fears of a severe reactor accident that would send large quantities of radiation into the environment. The film affected the American psyche regarding the safe operation of nuclear reactors, nuclear radiation effects, and nuclear meltdown. Anti-nuclear activists petitioned against new construction of nuclear power plants and no one wanted a nuclear power plant in their back yard.

The Nuclear Regulatory Commission imposed major changes on nuclear facilities since the accident.[53] Plant design and equipment requirements were upgraded and strengthened. Operator training and staffing requirements were improved. Additionally, emergency preparedness was enhanced to include NRC notification requirements.

Even though the U.S. has not built a new reactor in decades, designers have produced newer reactor designs with greater operating reliability and lower operating costs. The TMI accident solidified anti-nuclear safety concerns among activists and the general public, resulted in new regulations for the nuclear industry, and has been cited as a contributor to the decline of new reactor construction. For the industry to survive and grow, nuclear advocates must dedicate themselves to restoring the public's faith in the industry's safety record.[54] With an increase in public awareness regarding safety and regulations, The Department of Energy hopes to "promote secure, competitive and environmentally responsible nuclear technologies to serve the present and future energy needs of the U.S."[55]

Public Opinion

Changing economics, tightening natural gas availabilities, and environmental pressures now have utilities reconsidering the nuclear power option, but significant

hurdles remain.[56] Following accidents at the Three Mile Island and Chernobyl power plants, the U.S. public's attitude toward nuclear power has been mixed. The following addresses some of the most vocal arguments:

Nuclear energy cannot reduce our dependence on foreign oil. Nuclear-generated electricity powers electric trains and subway cars as well as autos today. It has also been used in propelling ships for more than 50 years. That use can be increased since it has been restricted by unofficial policy to military vessels and ice breakers. In the near-term, nuclear power can provide electricity for expanded mass-transit and plug-in hybrid cars. Small modular reactors can provide power to islands like Hawaii, Puerto Rico, Nantucket and Guam that currently run their electrical grids on imported oil. In the longer-term, nuclear power can directly reduce our dependence on foreign oil by producing hydrogen for use in fuel cells and synthetic liquid fuels.[57]

Nuclear energy is bad for the environment. Nuclear reactors emit no greenhouse gasses during operation. Over their full lifetimes, they result in comparable emissions to renewable forms of energy such as wind and solar. Nuclear energy requires less land use than most other forms of energy.[58]

Nuclear power is not safe. Nuclear energy is as safe as or safer than any other form of energy available. U.S. naval nuclear reactors have been supplying power and propulsion for its submarines and aircraft carriers since 1955 without incident, and no member of the military or public has ever been injured or killed in the entire 50-year history of naval or commercial nuclear power in the U.S. In fact, recent studies have shown that it is safer to work in a nuclear power plant than in an office.[59]

Nuclear power has a waste problem. Until the public can be shown that nuclear waste is safer than fossil-fuel waste and that it is reliably controlled…nuclear power in the U.S. will be constrained.[60] All of the used nuclear fuel generated in every nuclear plant in the past 50 years would fill a football field to a depth of less than 10 yards, and 96% of this "waste" can be recycled.[61] Increased fuel efficiency has led to a decrease in nuclear waste generation. The entire American inventory of waste stored at nuclear plants, after forty years of making trillions of kilo-watt hours of electricity comes to about fifty thousand metric tons.[62] This is minute compared to releases from hydrocarbon plants.

Most Americans don't support nuclear power. Public and political acceptance of nuclear power as a logical large-scale alternative to fossil fuel is higher than it has been in a generation.[63] Three out of four Americans say they favor nuclear energy. The long-term transformation in public opinion on nuclear energy is striking: Those in favor moved from 49 percent in 1983, when the question was first asked, to 74 percent today.[64]

Follow France's Lead

The French overcame many of the same issues and challenges that the U.S. nuclear industry faces today. Issues include regulatory oversight, waste disposal, and safety concerns. Motivated by their desire for energy security and independence, they accepted nuclear energy as a viable and sustainable option.

What made France embrace the concept of nuclear energy for energy independence? France does not possess any sizable deposits of fossil-fuels. Herbst and Hopley argue that "the French realized just how dependent and vulnerable their economy was to imported Middle East oil in 1956 when Egypt blocked the Suez Canal

and again in 1973 with the global Arab oil embargo."[65] To lessen their dependence on imported fossil fuels, the French government developed a robust nuclear power building program to construct six reactor plants per year. In France, the Executive branch plays a huge role in the formulation of new legislation. Since the government controls the majority of legislative seats, policies originating in the Parliament must meet the approval of the leaders of the Executive branch, even if the policy does not begin as part of the government's agenda. Because of this unique tie between executive and legislative branches, nuclear power was never a discussion for meaningful parliamentary debate.[66]

Nuclear power became the focus of French public opposition, provoking large - scale demonstrations. In 1971 French plans to locate the first reactor power plant in Bugey brought out 15,000 demonstrators.[67] Massive demonstrations were held at every construction site some culminating in violence.

With 59 reactors and a total capacity of over 63 gigawatts, Electricite de France (EdF) supplies over 426 billion kilowatt-hours per year of electricity. Behind Germany, France is the second largest electricity sector in the European Union. Behind Sweden, France has the second-lowest level of carbon emissions in Europe. Almost 80 percent of the country's electricity is provided for by nuclear power. This figure is approximately four times greater than the percentage of electricity generated by nuclear power in the U.S.

France's dependence on imported oil has been curtailed by its increased use of nuclear energy. France has become the largest net exporter of electricity in the

European Union.[68] Exporting 60 to 70 billion kilowatts-hours net of electricity each year for the past decade, France has become the world's largest exporter of electricity.[69]

To offset construction costs, the French decided to build fuel reprocessing facilities with surplus capacity to handle their spent fuel and international demand. As a global reprocessor France reprocesses waste from Germany to Japan. They also purchased one type of reactor, building plants more economically than nuclear facilities built in the U.S.[70] Unlike in the U.S., safety management was easier because lessons learned and best practices from one nuclear facility could be more easily shared at other French plants.

Current U.S. Nuclear Efforts

Matthew Wald, writer for the New York Times wrote

> The prospect of growing electricity demand, probable caps on carbon dioxide emissions and government loan guarantees prompted companies to tell the NRC that they wanted to build 28 reactors. Constellation Energy's announcement on October 9, 2010 that it had reached a road block with the federal government over the fee for a loan guarantee on a new reactor in Maryland is a sign of how much the landscape has been transformed.[71]

With the price of natural gas fluctuating with the decrease in electricity demand, the urgency to build new plants has diminished and probably no more than four new units will come on line by 2020. If the U.S. wants energy independence, like France, more emphasis should be placed on energy independence in the National Security Strategy. Congress' ability to pass climate change legislation, placing a tax on carbon dioxide emissions, would benefit the nuclear industry but an agreement within Congress cannot be reached. While several reactors have been put on hold, there are several sites under construction and firmly planned.[72]

The number of U.S. commercial reactor plants will slowly decrease as each reactor's operating license or license extension expires. If additional reactors are not built to support base load electricity demands, other electricity generation plants will not keep pace with the growing energy demand. Nuclear power will not totally replace the various electricity producing assets in the U.S., however it should play an increasing role in the nation's energy mix.

Conclusion

Fossil fuels are dwindling with increased consumption by the U.S., China, and India. As energy prices continue to rise, we must consider alternate energy sources to support our rebounding economy as well as meet global climate change concerns. The Obama administration has passed legislation and proposed incentives for financiers to build. If we want public buy-in for new nuclear construction sites, in their backyard, we must resolve a long term nuclear waste disposal site.

> As the passage of time separates us from negatively perceived events, such as Three Mile Island and Chernobyl, and should there be no other negative events, the public's approval of and openness to further nuclear energy expansion in the U.S. should continue to rise.[73]

Can the U.S. rely on nuclear energy for energy security? With the significant energy and environmental challenges facing the nation in this new century, the benefits of clean and safe nuclear energy are increasingly apparent.[74] Without energy security we leave ourselves vulnerable to disruptions and manipulation by oil providers. OPEC's oil embargo of 1973 demonstrated that U.S. is susceptible to oil disruption. The U.S. currently imports over 50 percent of the oil consumed from Venezuela, Nigeria, Mexico and several others. If the U.S. wants to avoid being manipulated by the political

instability of several energy producing countries we must come to depend on a more sustainable energy source.

America is not France or China, which are both moving ahead rapidly with nuclear technology.[75] The nation's decision to move forward with nuclear energy will depend on public opinion. If the U.S. government can persuade its citizens to accept the minimal risks and dangers currently associated with nuclear energy, the nation can establish energy independence and reduce the dependency on imported fossil fuels.

Endnotes

[1] Parker, Larry and Holt, Mark (March 9, 2007). Nuclear power: Outlook for new U.S. Reactors

[2] Herbst, Alan and Hopley, George, *Nuclear Energy Now* (New Jersey: John Wiley & Sons, Inc., 2007), 1-2.

[3] *Department of Energy Home Page*, http://www.energy.gov/energysources/fossilfuels.htm (accessed October 27, 2010).

[4] Herbst and Hopley, *Nuclear Energy Now*, 11.

[5] Daniel Howen, "World Oil Supplies are Set to Run Out Faster Than Expected, Warn Scientists, *"The Independent*, June 2007, http://www.independent.co.uk/news/science/world-oil-supplies-are-set-to-run-out-faster-than-expected-warn-scientists-453068.html (accessed December 17,2010)

[6] Fereidun Fesharaki, "Fossil Fuel use in China and India Forecasted to Continue Growth," July 22, 2010, http://www.eastwestcenter.org/news-center/east-west-wire/fossil-fuel-use-in-china-and-india-forecasted-to-continue-growth/ (accessed February 28, 2010).

[7] Herbst and Hopley, *Nuclear Energy Now*, 62.

[8] Peter Goodman, "Rising Energy Prices Inflate Costs of Suburbia and Beyond," New York Times, June 25, 2008, http://www.nytimes.com/2008/06/25/business/worldbusiness/25iht-exurbs.1.13973643.html (accessed December 18, 2010).

[9] Herbst and Hopley, *Nuclear Energy Now*, 48.

[10] Sharon Squassoni,"Nuclear Renaissance: Is It Coming? Should It?" Carnegie Endowment, October 2008, http://carnegieendowment.org/files/nuclear_renaissance1.pdf (accessed December 21, 2010)

[11] Herbst and Hopley, *Nuclear Energy Now*, 165.

[12] Barack H. Obama, *National Security Strategy* (Washington, D.C.: The White House, May 2010), 30.

[13] Herbst and Hopley, *Nuclear Energy Now*, 4.

[14] Congressional Research Service, "Energy Policy Act of 2005: Summary and Analysis of Enacted Provisions," March 8, 2006, http://ncseonline.org/NLE/CRSreports/06Apr/RL33302.pdf (accessed December 15, 2010).

[15] "Obama Renews Commitment to Nuclear Energy," February 16, 2010, linked from the MSN.COM Home Page at "Business," http://www.msnbc.msn.com/id/35421517/ns/business-stocks_and_economy/ (accessed December 15, 2010).

[16] Caldicott, Helen, *Nuclear Power is Not the Answer* (New York: The New York Press, 2006), 27.

[17] Caldicott, *Nuclear Power is Not the Answer*, 23-24.

[18] *Department of Energy Home Page*, http://www.ne.doe.gov/np2010/overview.html (accessed December 15, 2010)

[19] Herbst and Hopley, *Nuclear Energy Now*, 9.

[20] *Department of Energy Home Page*, http://www.nuclear.energy.gov/pdfFiles/ FinalReportonESPLessonsLearned.pdf (accessed December 15, 2010)

[21] Squassoni, "Nuclear Renaissance: Is It Coming? Should It?" 3.

[22] *Department of Energy Home Page*, http://www.nuclear.energy.gov/pdfFiles/ FinalReportonESPLessonsLearned.pdf (accessed December 15, 2010), 30.

[23] Squassoni, "Nuclear Renaissance: Is It Coming? Should It?" 2-3.

[24] Nuclearinfo.net Home Page, http://nuclearinfo.net/Nuclearpower/WebHomeCost OfNuclearPower (accessed December 26, 2010).

[25] Ibid.

[26] Ibid.

[27] James Lovelock, "Nuclear Energy: The Safe Choice for Now," *Environmentalists for Nuclear Energy*, July 2005, http://www.ecolo.org/lovelock/nuclear-safe-choice-05.htm (accessed 27 December 2010).

[28] Caldicott, *Nuclear Power is Not the Answer*, 60.

[29] Energy Information Administration Home Page, http://www.eia.doe.gov/cneaf/nuclear/ page/nuclearenvissues.html (accessed 26 December 2010).

[30] Ibid.

[31] Nuclearinfo.net Home Page, http://nuclearinfo.net/Nuclearpower/WebHomeCost OfNuclearPower (accessed December 26, 2010).

[32] Ibid.

[33] Robert Longley, "DOE Moves to Withdraw Yucca Mountain Application," *About.com*, March 4, 2010 (accessed December 27, 2010).

[34] *Department of Energy Home Page,* http://www.energy.gov/news/documents/DOE_ Motion_to_Withdraw.pdf (accessed 30 January 2011).

[35] Energy Information Administration Home Page, http://www.eia.doe.gov/cneaf/nuclear/ page/nuclearenvissues.html (accessed 27 December 2010).

[36] "U.S. Nuclear Fuel Reprocessing Initiative*," linked from Union of Concerned Scientists Home Page*, http://www.ucsusa.org/nuclear_power/nuclear_power_risk/nuclear_ proliferation_and_terrorism/us-nuclear-fuel.html (accessed 20 January 2011).

[37] "Kyoto Protocol," linked from *United Nations Framework Convention on Climate Change Home Page*, http://unfccc.int/kyoto_protocol/items/2830.php (accessed December 21, 2010).

[38] Ibid.

[39] Caldicott, *Nuclear Power is Not the Answer*, 167.

[40] Ibid.

[41] Herbst and Hopley, *Nuclear Energy Now*, 51.

[42] "Global Warming Versus Nuclear Power," *The New Scientist*, May 14, 2005 quoted in Helen Caldicott, Nuclear Power is Not the Answer (New York: The New York Press, 2006), 164.

[43] Cravens, *Power to Save the World*, 10.

[44] Tucker, *Terrestrial Energy*, 156.

[45] Caldicott, *Nuclear Power is Not the Answer*, 168.

[46] Cravens, *Power to Save the World*, 253.

[47] Tucker, *Terrestrial Energy*, 159.

[48] Ibid., 163.

[49] Caldicott, *Nuclear Power is Not the Answer*, 171.

[50] "Largest-ever Solar Project Approved in California," *National Resources Defense Council Home Page*, http://www.nrdc.org/media/2010/101025b.asp (accessed 30 January 2011).

[51] Tucker, *Terrestrial Energy*, 182.

[52] U.S. Nuclear Regulatory Commission Home Page, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html (accessed December 21, 2010)

[53] Ibid.

[54] Herbst and Hopley, *Nuclear Energy Now*, 155.

[55] *Department of Energy Home Page*, http://www.energy.gov/energysources/nuclear.htm (accessed December 27, 2010)

[56] Herbst and Hopley, *Nuclear Energy Now*, 26.

[57] Ibid.

[58] American Nuclear Society Home Page, http://www.ans.org/pi/resources/myths/ (accessed December 16, 2010).

[59] Ibid.

[60] Cravens, Gwyneth, *Power to Save the World* (New York: Vintage Books, 2008), 265.

[61] American Nuclear Society Home Page, http://www.ans.org/pi/resources/myths/ (accessed December 16, 2010).

[62] Cravens, *Power to Save the World*, 269.

[63] Chuck McCutcheon,"Global Warming Heats up a Nuclear Energy Renaissance," *The Christian Science Monitor*, August 2010, http://www.csmonitor.com/Environment/2010/0809/Global-warming-heats-up-a-nuclear-energy-renaissance (accessed October 27, 2010).

[64] *Nuclear Energy Institute Home Page,* http://www.nei.org/resourcesandstats/documentlibrary/publications/perspectiveonpublicopinion/perspective-on-public-opinion-june-2010/ (accessed December 16, 2010).

[65] Herbst and Hopley, *Nuclear Energy Now*, 97.

[66] Dorothy Nelkin and Michael Pollack, *The Atom Besieged: Antinuclear Movements in France and Germany*, http://mitpress.mit.edu/books/chapters/026264021X chap1.pdf (accessed 30 January 2011).

[67] Ibid.

[68] Herbst and Hopley, *Nuclear Energy Now*, 96.

[69] Ibid.

[70] Ibid.

[71] Matthew L. Wald, "Sluggish Economy Curtails Prospects for Building Nuclear Reactors," New York Times, October 11, 2010.

[72] "Nuclear Power in the USA," *World Nuclear Association*, http://www.world-nuclear.org/info/inf41.html (accessed December 27, 2010).

[73] Herbst and Hopley, *Nuclear Energy Now*, 25.

[74] Department of Energy Home Page, http://www.energy.gov/energysources/nuclear.htm (accessed December 21, 2010).

[75] Tucker, *Terrestrial Energy*, 380.